

Foliar Applied Rooting Solutions for Plant Propagation from Cuttings:

Historical Background and Utility

Joel Kroin, Hortus USA Corp., support@hortus.com, rootinghormones.com

INTRODUCTION

The propagation of plants from cuttings using foliar methods is easy:

- Take leafy cuttings in the growing state.
- Apply aqueous (water based) IBA rooting solutions to the leaves by spray or total immerse dip.
- Sticking is done either before or after treatment depending upon the method.
- Roots are produced at the basal end of the cuttings.

Today foliar applied aqueous IBA rooting solutions are successfully used to propagate leafy cuttings taken in the growing state. Fundamentals of the process seem obvious. It had been known for over a century that some substances were produced in leaves, causing plant growth regulation in other parts of the plant. These natural substances, called auxins, have been identified. The basic natural auxin, IAA, was found produced in leaves. Contained in aqueous solutions, auxins can be applied to leaves. These solutions can enter the vascular system of plants through pores in leaves called stomata. Inside the system, the auxins move by polar transport to the basal end of cuttings. Though physiological interactions, scientists believe that IAA becomes another natural auxin, IBA. Therefore, when an IBA in aqueous rooting solution is applied to leaves, it can enter the vascular system. IBA can be transported, with the leaf produced IAA, to the basal end. At the basal end, by processes still unknown by scientists, IAA and IBA induce cell division resulting in root formation.

BACKGROUND

For more than a century, botanists debated how plants regulate growth. One of the mysterious phenomenon, root cells form in apparently normal plant tissue. Julius Sachs (1892) proposed specific substances act to form leaves, roots, or stems, moving with polarity in specific directions. His theory was that the root

forming substance was formed in leaves and translocates to the lower parts of the plant, there stimulating root production.

The later generation scientist, Fritz Went was influenced by Sachs' ideas. Went's doctoral thesis (1928), developed the 'bio-assay' technique. Bio-assay is used to identify substances developed in tips of plants which translocate to lower portions of the plant for growth regulation. Using bio-assay, Went and Kenneth Thimann (1934) identified the plant growth regulator Indole acetic acid, IAA, as a natural substance produced in leaves. IAA has the ability to translocate within the plants' vascular system. Using IAA as a starting point, they identified other close compounds, 'auxins', which potentially have similar plant growth regulator activity.

Of the auxins, Indole butyric acid (IBA) and Naphthalene acetic acid (NAA) were found to have utility in plant growth regulation. Recently, IBA was found naturally occurring. After the discovery that auxins were important for root formation, it was well known, these natural substances were produced in inadequate amounts to initiate root formation on most plant cuttings. For those cuttings that cannot form roots on their own or are slow-to-root, external applications of auxins are required to achieve rooting.

After identification of the auxins, Went, Thimann, the Boyce Thompson Institute researchers, and other scientists, developed techniques to use them. Their research on root formation was limited to basal application, for intended root formation. They locally applied auxin based dry powders (rooting hormone powders), auxin solutions, (rooting solutions), or auxin containing lanolin pastes to the basal end of cuttings. Positive root formation was observed.

Believed to be the first studies, foliar applied auxin solutions were successfully used to root of carnation cuttings by D.W. Cheever (1967). The earliest published histology study on foliar applied aqueous IBA rooting solutions was Frederick Davies' PhD thesis (1978). Cuttings were taken in the growing state. Davies demonstrated root formation on *Ficus pumila* juvenile cuttings require lower IBA rates, with higher root numbers as compared to mature cuttings. (Davies and Joiner's article on their research is in this book.)

After the discovery of auxins, in Holland, the Amsterdam Chinin Factory (ACF) first produced commercial auxins under their Rhizopon division (1940). Rhizopon manufactures commercial plant rooting products, both dry dip powders and water soluble tablets to make rooting solutions. To improve use of the rooting solution products, the Rhizopon scientist Kees Eigenraam developed the first commercial foliar methods (1985). At the time, Eigenraam did not know the research by Davies. The first commercial users were Dutch growers propagating

chrysanthemum cuttings. These growers found, foliar application reduced labor and improved the root formation of cuttings.

Joel Kroin, of Hortus USA, first met Eigenraam in 1989. They discussed the foliar methods that were newly used. Other than Rhizopon's data sheets, Kroin could not find anything written about foliar methods. Literature of the time said plant propagation from cuttings was limited to basal methods. Lacking foliar nomenclature and other basic information, Kroin termed the 'Spray Drip Down Method' and 'Total Immerse Method'. Over the years, Kroin and Eigenraam improved and documented foliar methods.

For use of foliar and basal methods, Hortus USA, introduced US growers to Rhizopon AA Water Soluble Tablets (measured by counting tablets) (1993). Tablets, when dissolved in water, make aqueous (water based) IBA rooting solutions. Among the first US foliar method users were the Yoder chrysanthemum propagators in Florida. Soon after, Yoder established their perennial propagation facility, now called Aris Green Leaf Plants, in Lancaster PA. There they began using the foliar Spray Drip Down Method. Keeping concise records, they established rates for thousands of named plant varieties. Their cuttings are taken from juvenile stock plants, resulting in rooting uniformity. Significant for propagators of high volume annual and perennial plants, foliar methods save labor. Cuttings are treated in bulk rather than individually. Low rooting solution rates result in low material cost. Hortus USA developed Hortus IBA Water Soluble Salts, measured by weighting powder, to meet the aqueous (water based) IBA rooting solution needs of plant propagators.

Soon after, Bailey Nurseries' research director Sam Drahn, started to use the Spray Drip Down Method to root woody ornamental cuttings. Based upon his data, it became apparent, the rates for woody ornamental plant cuttings are similar to those obtained by Dr. Davies' juvenile cuttings, and the perennial cuttings of Green Leaf Plants.

Using this information, rates were established for two basic groups of cutting rates for juvenile leafy cuttings that are in the growing state. Rates for mature leafy cuttings are higher than the rates for juvenile cuttings.

Cuttings of perennial and woody ornamental plants require the same rates; the midpoint trial rate is about 1000 ppm IBA using Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. (Drahn's article on his research is in this book.)

Cuttings of annual plants require very low rates; the midpoint trial rate is about 125 ppm IBA using Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

The technology of foliar application of aqueous (water based) IBA rooting solutions are based upon plant physiology. Water is the

natural fluid carrier in the plant's vascular system. As previously described, it has been found that both IAA and IBA are naturally produced by plants. IAA produced in leaves is usually inadequate for root initiation. IAA is unstable; it decays rapidly due to biological factors, light, and heat. Whereas, IBA is stable when needed for root initiation. Compared with IAA, IBA has greater ability to initiate roots. Various studies suggest IBA may be a very simple 'conjugate' of IAA and must be converted to IAA by β -oxidation. As such, either IAA or IBA may be the substance that induces cell division and root initiation. The plant can use the applied IBA as a booster where natural IAA is not sufficient for root formation. It has also been shown, auxins translocate from the apical to basal portions of the plant section.

The foliar entry point of applied aqueous (water based) IBA rooting solution into the plant is through the structure called 'stomata'. While mostly found on the underside of leaves, stomata can also be found on other plant parts including upper leaf surfaces, stems and specialized structures. Their function is to regulate interchange of gases, including water vapor, between the plant and the environment. The stomata have two principal parts, the internal pore and the surrounding guard cells. Guard cells regulate the size of the pores. For foliar application of rooting solutions to work successfully the pores must be open. Studies show stomata are open when cuttings are well hydrated and when temperatures and other factors allow translocation of gas, vapor and liquid. Stomata close when cuttings are wilted.

Stomatal cavities contain air spaces and leaf mesophyll cells that can absorb fluids such as aqueous (water based) IBA solutions. Rooting solution absorption is caused by pressure differentials between the relative humidity outside the leaf and the stomatal cavity, (for example, VPD 'vapor pressure deficit'). After the applied IBA rooting solution enters the leaves, it is absorbed and enters vascular bundles (the phloem). The bundles facilitate translocation of fluids through the plant. Along with leaf produced IAA, the applied and natural IBA is translocated in a polar direction to the basal end of the cuttings; adventitious roots are initiated and formed. If an excess of IBA is foliar applied, it may be possible for it to return, by non-polar transport, to upper portions of the cutting. If so, herbaceous cuttings may exhibit leaf curls or spotting. If the excess were not too high, the cuttings will still produce proper rooting and growth. Lowest possible IBA rates avoid such phytotoxicity.

METHODS

Three basal and two foliar methods are successfully used to propagate plants from cuttings.

Three basal methods, the Dry Dip, Basal Long Soak and Quick Dip Methods, have been used since discovery of auxins. Cuttings of active growing or dormant annuals, perennials, and woody plants can be used.

The Dry Drip Method uses dry powder rooting hormones. Basal ends of the cuttings are dipped into the powder then stuck. The Basal Long Soak Method, was well used through 1950's. The method uses rooting solutions. Basal ends of the cuttings are soaked into the rooting solution for several hours then stuck. The Quick Dip Method uses rooting solutions. Basal ends of the cuttings are dipped into the rooting solution for a few seconds then stuck.

Two foliar methods, the Spray Drip Down and Total Immerse Methods have been in use as described previously. Cuttings of actively growing or dormant annuals, perennials, and woody plants are used. The methods use aqueous (water based) IBA rooting solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. The Spray Drip Down Method is used on cuttings that are first stuck. The rooting solution is sprayed onto the leaves until liquid drops are seen to drip down. Drop formation on the top and bottom of the leaves is preferred. The Total Immerse Method has cuttings totally immersed in the rooting solution for a few seconds then stuck. Rates for the two Methods are similar.

Compared with basal methods, foliar methods have improved rooting quality, reduced misses, reduced labor cost, and material cost savings. Basal methods can be used on cuttings taken all year. Foliar methods can be used on cuttings taken growing state. Selection of the method to be used for particular cuttings should be based upon facility needs, direct and indirect cost, the plant variety, and growing state. In the same facility, some plant taxa, such as selected cultivars of Chrysanthemums or Roses, are sometimes propagated in parallel using either foliar or basal methods.

ROOTING STATIONS AND LINER PROPAGATORS USE FOLIAR METHODS

The Spray Drip Down Method is used by annual plant growers including Dummen's Red Fox rooting stations and Yoder Chrysanthemums. Some perennial plant grower users are Aris' Green Leaf Plants and Keepsake Plants. Many woody plant growers also use it, including Bailey Nurseries. Total Immerse is extensively used on crops such as many perennials, and other plants such as phlox, dianthus, and heder (ivy). The Total Immerse Method is also used on tissue culture plantlets when transplanting in the greenhouse stage.

FOLIAR METHODS

THE TOTAL IMMERSE METHOD

The Total Immerse Method is used on cuttings taken in the growing state. Small or large homogeneous plant lots can be used. To avoid cross contamination between production lots, cuttings must be clean and disease free. Cuttings are treated then stuck. Rooting Solutions are made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

Cuttings are dipped into the rooting solution until the leaves are completely covered with liquid for about five seconds. The result is, leaves have treatment on both their tops and bottoms. After draining, the cuttings are stuck into media. A simple tub and strainer basket are used to treat the cuttings. It is important not to over-load baskets to avoid cutting breakage. Dipped cuttings bring biological materials into the solution. Disposing of the rooting solution between dissimilar cutting lots is best. When homogeneous lots are treated, the rooting solution should be disposed at the end of the production day or period. Personnel Protection Equipment (PPE) is required as stated on the product labels.

THE SPRAY DRIP DOWN™ METHOD

The Spray Drip Down Method can be used on small or large plant lots. Cuttings of different types can be treated together. Cuttings are stuck then treated. Rooting solutions are made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets.

After sticking cuttings, the rooting solution is sprayed onto the leaves until there is a drip down. The drips are visual indicators of the adequate amount of applied solution. Leaf treatment should be both their top and bottom. An excess application is best. After spray treatment, misters can be turned on after about 3/4 hour or until the rooting solution dries on the leaves. Typical application

uses about 10 m²/ liter (190-220 ft²/gallon). Various types of sprayers are used such as backpack, hydraulic, boom, or custom made. The rooting solution is used one time. Since the unused rooting solution is kept in the sprayer tank, there is no possible rooting solution contamination between production lots. No personnel protection equipment (PPE) is required to stick untreated cuttings. Thin gloves may be used solely for sanitary purposes.

SOLUTIONS USED BY FOLIAR METHODS

Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets are US EPA registered. Mixed with ordinary water, they are used to make aqueous (water based) IBA rooting solutions. Their labels approve use by basal and foliar methods. When used by foliar methods, it is not necessary to use of wetting agents with their solutions. Where foliar and basal methods are used in the same facility, it is only necessary to inventory one or both products for any method.

A gram scale is used to weight Hortus IBA Water Soluble Salts or large quantities of Rhizopon AA Water Soluble Tablets. Or, Tablets can be counted. The Salts or Tablets are dissolved in water. If a concentrate is made, it can be added to the production tank; water is added to bring to the required liquid volume. Warm water, at hand washing temperature, makes dissolving easier than when using cold water. For ease of handling, concentrate Hortus IBA Water Soluble Salts aqueous IBA rooting solutions can be made to over 80,000 ppm IBA. Solutions should be made soon before use. Unused rooting solutions can be kept a short period. Solutions that have cuttings dipped-in should be discarded soon after use.

RATES (See page 30-38)

The Spray Drip Down and Total Immerse Methods use similar rates for cuttings. Rates used by the Basal Quick Dip Method are usually too high for foliar methods. Juvenile cuttings require lower rates than mature cuttings. Plants growers generally know which of their cuttings are seasonally easy or hard-to-root and adjust their rates. Where leaf distortions occur, the rates are to be adjusted downward.

Annual and tender plant cuttings, and some juvenile cuttings, selected rates at about 80 to 200 ppm IBA using solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. The midpoint trial rate is about 125 ppm IBA.

Perennial and woody ornamental cuttings require similar rates. Selected rates at about 500, 1000, and 1500 ppm IBA using solutions made with Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets. The midpoint trial rate is about 1000 ppm IBA. Mature cutting rates above 1500 ppm IBA are rarely used. Juvenile and tender cuttings, rates below 500 ppm IBA are used.

RATES: DIVISIONS AND CUTTING TRANSPLANTS.

The Spray Drip Down Method is used to treat divisions and young rooted cutting transplants after transplanting. Cutting transplants require the same rates as if they are unrooted. Ornamental grasses transplant divisions require rates as if they were annual cuttings.

RATES: TC TRANSPLANTS.

When transplanting tissue culture plantlets, the Total Immerse Method is used with Rhizopon AA Water Soluble Tablets at about one to three tablets/liter solution. As a guideline for TC rate selection, the rate for cultivated highbush blueberry TC transplants is about two Rhizopon AA Water Soluble Tablets/liter solutions (One tablet/liter solution was shown inadequate and three tablets/liter solution formed callus mis-formation.)

THE CUTTINGS

Leafy cuttings are taken from stock plants in the active growing state. There must be internal sap flow. Dormant cuttings are not used; there are limited metabolic activities and restricted sap flow and vascular uptake. Leafless cuttings have no 'leaf' entry points. Aqueous (water based) IBA solutions, using Hortus IBA Water Soluble Salts or Rhizopon AA Water Soluble Tablets, are applied to leaves. The rooting solution enters the plant's vascular system through open pores in leaves through 'stomata' structures. Stomata are open in a temperature range about 60-90°F (16-32°C), provided cuttings are well hydrated. After entry into the vascular system, the IBA translocates to the basal end where it helps to initiate roots.

The rules for taking annual, perennial and woody plant cuttings are simple. Take leafy cuttings in the active growing state. Juvenile cuttings have better rooting capability compared to mature cuttings. For root formation, juvenile cutting require lower Rooting Solution rates than for mature cutting. To maintain juvenility, use 'cuttings-from-cuttings' when possible. For foliar methods, dormant or leafless cuttings, these are propagated by basal methods. Generally, cuttings that have nodes at the basal end do not root as well versus cuttings with inter-nodes. Some plant growers cut the

tips of large leaf cuttings to obtain more cuttings in a propagation tray. The cut causes a wound that is open to infection. Wounds in the tip area create competing 'sinks', which ties up valuable resources (metabolites) to heal the leaf wound, rather than induce root formation at the basal end.

FAVORABLE PROCEDURES

TEMPERATURE.

When using foliar methods it is important not to apply in cold propagation areas or use cold solutions. Cuttings taken from coolers must be brought up in temperature before treatment. The standard foliar application temperature range for cuttings and solutions should be about 60-90°F (16-32°C), provided the cuttings are hydrated.

When propagation is done in locations where day temperatures are high, spraying is done early in the morning after sticking when temperatures are cool. In south Florida, sticking is done during the hot time of day, with workers cooled under mist. Spraying is done early the day after sticking when temperatures are cool.

TIMING BETWEEN STICKING AND TREATMENT BY THE SPRAY DRIP DOWN METHOD.

Davies and Joiner's studies (1980) showed that there was a variation in rooting after several days between sticking and treatment. For example, it is best to use foliar auxin applications within the first 48 hours of sticking. There was a decline in rooting after waiting more than a week to treat with IBA rooting solutions. Hortus USA's trials determined that it is best to treat the same day, or the following morning, after sticking.

Many growers have found root formation increase when, after sticking, using three day sequential Spray Drip Down Method at the same rate each day. Perennial and woody ornamental develop improved roots when treated at about 750-1000 ppm IBA using Hortus IBA Water Soluble Salts solutions.

PERSONAL PROTECTIVE EQUIPMENT.

(Reference the product label for specific PPE)

When using the Spray Drip Down Method, treatment workers doing spraying must use appropriate PPE. It is best to spray while other workers are not in the production area. This may be done at the end of the work day when other workers are away. Workers who only stick do not require PPE since cuttings are untreated.

HYDRATION.

Cuttings should use well hydrated cuttings when using foliar methods. Wilted cuttings have closed stomata. The rooting solution must enter the leaf through open pores in the stomata. Solutions entry is within a few minutes after rooting solution application. Some European chrysanthemum propagators advise successful Spray Drip Down Method on slightly limp leaf cuttings. When using the Spray Drip Down Method, mist systems must be turned off before spraying. This reduces dilution of the rooting solution. After spray treatment, misters can be resumed after about 3/4 hour or until the rooting solution dries on the leaves

LABOR SAVINGS AND CONTROL.

Foliar methods have reduced labor cost; sticking batch treating cuttings is faster than individual hand sticking of cuttings by basal methods. Foliar methods have no 'misses' as may happen with basal dip methods. Foliar methods use lower rates, and reduced material cost, as compared with basal methods.

LEVELING CROPS BY SECONDARY APPLICATION.

To level crops, secondary weekly Spray Drip Down Method foliar applications are used on leafy cuttings in the active growing state, at rates similar to the first initial rate. First application may be any method.

For sequential day application, in this book see the article "Propagate Plants from Cuttings Using Foliar Applied Aqueous IBA Rooting Solutions. Tips: Do's and Don'ts", section "Sequential Treatment".

HYBRID PROPAGATION SYSTEMS.

Cuttings may be treated at time of sticking by any basal (Quick Dip, Long Soak, Dry Dip) or foliar (Spray Drip Down, Total Immerse) method. Then, the Spray Drip Down Method is used for second or third treatment; application will level crops.

Often growers will use either the Quick Dip, Long Soak, Dry Dip, Spray Drip Down, or Total Immerse Method to propagate some crops. Then, in parallel, use other method for other crops. Selection of the method can be dependant upon the plant variety, time of the year, or facility factors.

In a chrysanthemum propagation facility, it is common to hybrid operations. At the same or other times in the same facility, the Dry Dip Method (using dip rooting hormones) are used on some varieties; the Spray Drip Down Method (using rooting solutions) are used on other varieties.

ADVANTAGES OF FOLIAR APPLIED AQUEOUS (WATER BASED) IBA ROOTING SOLUTIONS

- Quality: Foliar methods produce high rooting quality due to uniform treatment.
- Low material cost: Foliar methods use low rooting solution rates and reduced material cost compared with the high rate basal Quick Dip Method.
- Low labor cost: Sticking by foliar methods use on third the labor of basal treated cuttings. Foliar methods have bulk treated cuttings. Basal methods have individually treated cuttings.
- Uniform rooting results: there are no misses. Spray Drip Down Method treatment is done by skilled workers. Total Immerse Method is done in bulk.
- No cross contamination: The Spray Drip Down Method reduces cross contamination of diseases and pathogens; solutions are used one time.
- Reduced Personal Protective equipment: PPE is not required by workers doing sticking by the Spray Drip Down Method; no rooting solution is handled.
- Hortus IBA Water Soluble Salts and Rhizopon AA Water Soluble Tablets have zero hour Restricted Entry Interval (REI).
- Crops can be leveled: secondary spray application of the rooting solutions to planted crops can level crops.

REFERENCES AND ADDITIONAL READING

- Cheever, D.W. 1967. Rooting of carnation cuttings. Colorado Flower Growers Association, Bulletin 206, June 1967:1-6.
http://hortus.com/IBAarticles/Cheever_1967.pdf
- Davies, Jr., F.T. 1978. A histological and physiological analysis of adventitious root formation in juvenile and mature cuttings of *Ficus pumila* L. Dissertation Presented to the Graduate Council of The University of Florida, Gainesville.
http://hortus.com/IBAarticles/Davies_1978.pdf
- Davies, F.T. Jr. & Joiner, J.N. 1980. Growth regulator effects on adventitious root formation in leaf bud cuttings of juvenile and mature *Ficus pumila* L., J. Amer.Soc.Hort.Sci. V105:91-95.
http://hortus.com/IBAarticles/Davies_1980A.pdf
- Drahn, S. 2007. Auxin application via foliar sprays. Combined Proceedings of the International Plant Propagators' Society. V57.
http://hortus.com/IBAarticles/Drahn_2007.pdf
- Epstein E, Chen K, Cohen C. 1989. Identification of indole-3-butyric acid as an endogenous constituent of maize kernels and leaves. Plant Growth Regulation V8:215-223.
http://hortus.com/IBAarticles/Epstein_1989.pdf
- Greene, R. A History of Botany 1860-1900. Oxford Press. 1909.
<https://archive.org/details/historyofbotany00gree>
- Ludwig-Muller, Vertocnik, Town. 2005. Analysis of indole-3-butyric acid-induced adventitious root formation on *Arabidopsis* stem segments. J Exp Botany. V56:418,2095-2105.
<http://jxb.oxfordjournals.org/content/56/418/2095.full.pdf+html>
- Liu, Barkawi, Gardner, Cohen, 2012. Transport of indole-3-butyric acid and indole-3-acetic acid in *arabidopsis* hypocotyls using stable isotope labeling. Plant Physiology V.158:1988-2000.
<http://www.plantphysiol.org/content/158/4/1988.full.pdf+html>
- Thimann, K.V. and Went, F. 1934. On the chemical nature of root forming hormone.
http://hortus.com/IBAarticles/Thimann_1934.pdf